

10.0 IDENTIFICATION AND INITIAL SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS

This section presents technologies and process options that may be implemented to meet the general response actions identified in Section 9.0. Technologies and process options were evaluated and initially screened to eliminate infeasible or ineffective technologies from further consideration. This preliminary screening was qualitative, not quantitative, in nature and based only on the technical implementability of the process options (EPA 1988a). The initial screening of remedial technologies and process options is summarized in Table 10-1.

Remedial technologies are defined as general categories or types of remedies for response actions. Remedial process options are specific methods to implement a technology. The following sections discuss process options for each technology.

10.1 MONITORING

A groundwater monitoring program is implemented for the No Action response action to track contaminant plume movement. Monitoring data can be used as a valuable source of information if further action is required in the future.

Initial Screening - This technology has been retained for further evaluation as required by the NCP.

10.2 GROUNDWATER USE RESTRICTIONS

To protect public health from ingestion of contaminated groundwater, the use of such water must be restricted when contaminants exceed acceptable drinking water levels. An existing wellfield may have specific wells decommissioned or new wells may be installed in appropriate uncontaminated areas, or some other alternate water supply must be designated.

Initial Screening - The groundwater use restriction is considered potentially feasible because it is implementable and protects the public, and has therefore been retained for further evaluation in Section 11.0.

10.3 VERTICAL AND HORIZONTAL BARRIERS

The containment technology uses processes that provide vertical and horizontal barriers to the flow of contaminated groundwater.

Table 10-1

INITIAL SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS
 FOR GROUNDWATER

General Response Action	Technology	Process Option	Preliminary Screening Comments
No Action	Monitoring	Monitoring	Required by NCP
Institutional Actions	Groundwater use restrictions	Alternate Water Supply	Potentially feasible
Containment	Vertical Barrier	Slurry Wall	Not feasible due to large plume area and aquifer depth
		Grout Curtain	Not feasible due to large plume area and aquifer depth
		Steel Sheet Piling	Not feasible due to large plume area and aquifer depth
		Passive Treatment Walls	Not feasible due to large plume area
	Horizontal Barrier	Grout Injection	Not feasible due to large plume area
Collection/Treatment/End Use	Collection	Extraction	Extraction Wells
			Municipal Supply Wells
	Subsurface Drains	French Drain	Not feasible due to large plume area and aquifer depth
	Treatment	Biological	Aerobic Oxidation
			Anaerobic Digestion
			Not feasible, undemonstrated for chlorinated organic compounds
			Not feasible, undemonstrated for chlorinated organic compounds

Table 10-1 (Cont'd.)

INITIAL SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS
 FOR GROUNDWATER

General Response Action	Technology	Process Option	Preliminary Screening Comments
Treatment (Cont'd.)	Physical/Chemical (On-Site)	Aqueous-Phase Granular Activated Carbon (GAC)	Potentially feasible
		Air Stripping with Vapor-Phase GAC Treatment of Off Gas	Potentially feasible
		Air Stripping with Advanced Oxidation Off-Gas Treatment	Not feasible, undemonstrated technology for off-gas treatment.
		Air Stripping with Off Gas Treatment by Incineration	Not feasible due to large volume of off-gases.
		Air Stripping with Off-Gas Treatment by Resin Based Adsorption (Padre System)	Potentially feasible
		Advanced Oxidation (Ozone)	Potentially feasible
		Advanced Oxidation (Ozone/Peroxide)	Potentially feasible
		Advanced Oxidation (UV)	Potentially feasible
		Reverse Osmosis	Not feasible, undemonstrated for chlorinated organic compounds
		Ion Exchange	Not feasible, undemonstrated for chlorinated organic compounds
		Precipitation	Not feasible, undemonstrated for chlorinated organic compounds
		Air Sparging	Not feasible due to limited information
		Vacuum Vapor Extraction	Not feasible because it is in pilot-scale status
		Hot Water or Steam Flushing/Stripping	Not feasible because it is in pilot-scale status

Table 10-1 (Cont'd.)

INITIAL SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS
 FOR GROUNDWATER

General Response Action	Technology	Process Option	Preliminary Screening Comments
Treatment (Cont'd.)	Off-site	POTW	Potentially feasible
		RCRA Facility	Not feasible for large volumes of groundwater
	In-situ	Oxygen Enhancement with Hydrogen Peroxide Oxygen Enhancement with Air Sparging Permeable Treatment Beds Chemical Oxidation	Not feasible due to large plume area and aquifer depth
		Other	Natural Attenuation with Monitoring
End Use	On-site Discharge of Treated Water	Reinjection	Potentially feasible
		Surface Drainage	Potentially feasible
	Off-site Discharge of Treated Water	POTW	Potentially feasible
		Municipal Water Supply	Potentially feasible

Process option that is screened out.

10.3.1 Slurry Wall

Areas of groundwater contamination are surrounded by a soil (or cement) bentonite slurry-filled trench. Slurry walls can be constructed to depths of up to 100 feet. Testing during construction and groundwater monitoring after construction are needed to ensure that the slurry wall barrier is providing the permeability required.

10.3.2 Grout Curtain

Grout curtains are functionally similar to slurry walls, but they differ in the method of construction. Drilled holes are filled with grout to complete the barrier instead of a backfilled trench. The drilled holes must be overlapped to construct an impermeable barrier.

10.3.3 Steel Sheet Piling

This process option uses interconnecting steel sheets to provide an impermeable barrier. Sheet piling is commonly used in the construction industry to shore the walls of excavations while building subterranean structures.

10.3.4 Passive Treatment Walls

A permeable reaction wall is installed across the flow path of a contaminant plume, allowing the plume to passively move through the wall. The halogenated compounds are degraded by reactions with a mixture of porous media and a metal catalyst. Passive treatment walls are often effective for only a short time because they lose their reactive capacity, requiring replacement of the reactive medium.

10.3.5 Grout Injection

Grout is pressure-injected to depths through closely spaced drilled holes. The subsurface grout barrier prevents vertical migration of contaminated water. It is difficult to ensure the horizontal continuity of the barrier and, therefore, the effectiveness of the barrier to prevent vertical migration is questionable.

Initial Screening - This technology and its process options are not considered feasible at Muscoy due to the large plume area and aquifer depth, and have not been retained for further evaluation.

10.4 EXTRACTION

The extraction technology includes two process options or types of wells for extraction of groundwater. These wells are either extraction wells specifically located to extract contaminated groundwater, or existing municipal supply wells.

10.4.1 Extraction Wells

Groundwater extraction wells are specifically designed to collect contaminated groundwater from specific vertical and horizontal plume areas in an aquifer. This allows the groundwater collection system to establish a zone of capture relative to the contaminant plume. Often a mathematical model is used to

1 predict the response of an aquifer to pumping, and to assist in designing an extraction well system that
2 creates the desired zone of capture, and can be used to estimate future states of contamination.

3 Initial Screening - Groundwater extraction well systems are considered potentially feasible because of the
4 ability to capture groundwater at the depths in the Muscoy aquifer where TCE and PCE are located, and
5 are retained for further evaluation in Section 11.0.

6 **10.4.2 Municipal Supply Wells**

7 Municipal supply wells can be used much like extraction wells to collect contaminated groundwater.
8 However, well construction is an important consideration when evaluating an existing well for suitability
9 as a collection well: these wells typically are designed to extract groundwater from aquifer zones that
10 produce high quality drinking water and not for a zone of contaminant capture, which is desirable for
11 remediation of an aquifer.

12 Initial Screening - Municipal supply wells can be incorporated into the remedy because they can be used
13 as extraction wells to extract water at the proper depths where TCE and PCE are located, and have been
14 retained for further evaluation.

15 **10.5 SUBSURFACE DRAINS**

16 Subsurface drains, sometimes referred to as French drains, consist of perforated pipe placed in a trench
17 below the groundwater surface. The trench is lined with geotextile fabric to prevent plugging of the drain
18 with fine soils and backfilled with gravel to allow groundwater to move freely into the perforated pipe.
19 Contaminated groundwater is typically pumped from a sump connected to the sections of perforated pipe.

20 This process option is best suited for contaminants that are less dense than water. These contaminants
21 normally do not migrate to deeper areas in the aquifer. Further, application of this process is limited to
22 shallow aquifers.

23 Initial Screening - This technology is generally used to collect small volumes of shallow groundwater and
24 is not considered feasible for the large volumes of contaminated groundwater over twenty feet deep such
25 as at Muscoy, and has not been retained for further evaluation.

26 **10.6 BIOLOGICAL TREATMENT**

27 Two alternative process options, aerobic oxidation and anaerobic digestion, are considered as biological
28 treatment. Both processes use microbial organisms to break down contaminants into less toxic
29 compounds. Biological treatment can be applied in-situ or ex-situ. In cases of in-situ application,
30 contaminated groundwater is not extracted from the aquifer and microbes and nutrients are introduced
31 in the contaminated aquifer via injection or extraction well systems to degrade the contaminants. In cases
32 of ex-situ application, contaminated water is extracted from the aquifer and brought to the ground surface
33 where it is treated with microbes.

10.6.1 Aerobic Oxidation

Aerobic oxidation involves the biological removal of organic constituents from water by the action of microorganisms in the presence of free dissolved oxygen. Aerobic biological treatment results in the conversion of the organic compounds to intermediate organic by-products and finally to carbon dioxide and water. The result is the organic compounds are actually destroyed by the action of the bacterial organisms in water. However, an organic sludge is produced which must be disposed of in an acceptable manner.

Aerobic biological treatment systems are not readily adaptable for removal of chlorinated VOC constituents from contaminated groundwater. A disadvantage is the process generates a waste stream. Also, if parameters change, such as microorganism concentrations, the process becomes unstable.

Initial Screening - This technology is undemonstrated for chlorinated organic compounds (e.g., TCE and PCE) and has not been retained for further evaluation.

10.6.2 Anaerobic Digestion

Anaerobic digestion involves the biological removal of organic constituents from water or sludges by the action of microorganisms in the absence of oxygen. Anaerobic digestion results in the conversion of the organic compounds to intermediate organic acid and other by-products, and ultimately to carbon dioxide and methane. This process produces a sludge solid residual which requires disposal. Anaerobic digestion is similar to aerobic oxidation except that the reactions occur at a slower rate and less sludge is produced.

Anaerobic biological treatment systems are not readily adaptable for removal of chlorinated VOC constituents from contaminated groundwater. They have operational sensitivities which create a potentially unstable process, plus the generation of a solid waste stream.

Initial Screening - This technology is undemonstrated for chlorinated organic compounds, and has not been retained for further evaluation.

10.7 PHYSICAL/CHEMICAL TREATMENT (ON-SITE)

10.7.1 Aqueous-Phase Granular Activated Carbon

Aqueous-phase GAC is commonly used to remove VOC constituents from extracted groundwater, and is most effective for organic compounds with molecular weights from 100 to 5,000 g/mol. The molecular weights of TCE and PCE are 131 g/mol and 166 g/mol, respectively. Aqueous-phase GAC involves the removal of VOCs from the contaminated groundwater by passage of the water through a packed bed of GAC to transfer the VOCs from the aqueous phase to the solid phase by adsorption. The treated groundwater then passes out of the bottom of the GAC unit for additional treatment or subsequent discharge.

Spent GAC can be regenerated at either on-site or off-site facilities usually by heating with steam. The new or regenerated GAC may be returned to the bed for renewed contact with the contaminated groundwater and additional adsorption of the VOC compounds, where the cycle is repeated. Spent

carbon can be disposed of in a landfill or incinerated in a manner consistent with appropriate state and/or federal regulatory requirements. Carbon consumption can be reduced significantly with a destructive pretreatment technology such as advanced oxidation.

Initial Screening - Aqueous-phase GAC is considered potentially feasible and has been retained for further evaluation.

10.7.2 Air Stripping

Air stripping is a common method to remove contaminants from groundwater. The technology facilitates the contact of the contaminated water with air to transfer VOCs from the aqueous to the gas phase. Typical air stripping systems employ the countercurrent contacting of air with water in a vertical packed tower. The tower is filled with a packing material that substantially increases the surface area of the contaminated water which comes in contact with the air. Water enters the top of the air stripping tower and air enters the bottom. Treated groundwater is collected in a sump at the bottom of the tower and discharged for further treatment.

To meet EPA VOC emission standards, site contaminants transferred from the aqueous phase to the gas phase are generally passed through an emissions control device to minimize release of contaminants to the atmosphere. The VOCs in the off gas from the air stripping tower can normally be removed by passage through a vapor-phase activated carbon adsorption or resin based adsorption or advanced oxidation system, or by some type of gas stream incineration system. Although the SCAQMD identifies vapor-phase activated carbon adsorption as the BACT, other emissions control options are evaluated in this report.

Air Stripping with Vapor-Phase GAC Treatment of Off-Gas - Off-gas treatment using GAC is commonly used to remove VOC components from vapors. The carbon is used and regenerated in the same manner described in Subsection 10.7.1 for aqueous-phase GAC.

Initial Screening - Air stripping with GAC off-gas treatment is considered potentially feasible because it is demonstrated to be a feasible technology for removing TCE and PCE, and has been retained for further evaluation.

Air Stripping with Advanced Oxidation Off-Gas Treatment - Off-gas treatment using advanced oxidation is considered an innovative technology which oxidizes organics in off-gas vapors through a reaction with ozone or another oxidizing material. This process, as applied to groundwater, is discussed further in Subsection 10.7.3 below.

Initial Screening - Air stripping with advanced oxidation off-gas treatment is an unproven technology for vapor phase treatment and has not been retained for further evaluation.

Air Stripping with Off-Gas Treatment by Incineration - The contaminants that are transferred to the vapor phase from the air stripping process are thermally destroyed in an incinerator. This system requires a substantial amount of supplemental fuel to achieve the necessary air temperatures to accomplish complete combustion. Also, there is the potential for the production of toxic vapor by-products from combustion of chlorinated VOCs that would require an additional treatment system for removal.

1 Initial Screening - Air stripping with incineration off-gas treatment is not considered feasible for the
2 expected off-gas flow rates.

3 **Air Stripping with Off-Gas Treatment by Resin Based Adsorption** - Off-gas treatment using resin
4 based adsorption is a new process; such a system is being designed for the Newmark North Treatment
5 Plant at Newmark OU. The system consists of specialized resin based adsorbents that are regenerated
6 automatically on site. The off-gas (passing through the system) is absorbed by the resin. During the
7 desorption cycle, VOCs are recovered from the absorbents, condensed as a liquid, and transferred to an
8 external condensate tank.

9 Initial Screening - Air stripping with off-gas treatment by Padre system is considered potentially feasible,
10 and has been retained for further evaluation.

11 **10.7.3 Chemical Oxidation**

12 The chemical oxidation technology includes three processes that use oxidants to remove contaminants:

13 **Advanced Oxidation (Ozone)** - Ozone oxidation involves the removal of organic constituents in water
14 by reaction with an oxidizing material, ozone, to decompose the contaminants. The oxidation process
15 results in the actual destruction of the organic compounds to carbon dioxide and water plus other
16 components in place of the transfer of the substance to the gaseous or solid phases. Ozone oxidation is
17 most effective for removal of organic compounds in low concentration ranges.

18 Initial Screening - Advanced oxidation with ozone is considered potentially feasible because it is a
19 recently demonstrated destructive technology for TCE and PCE, and has been retained for further
20 consideration.

21 **Advanced Oxidation (Ozone/Peroxide)** - This process is identical to the ozone oxidation process, with
22 the exception that ozone and hydrogen peroxide are used as oxidizing agents. A system for the City of
23 Southgate, similar to the system required for the Muscoy Plume OU, has been performing satisfactorily,
24 and suggests that advanced oxidation may be an appropriate process for treatment.

25 Initial Screening - Advanced oxidation using ozone and peroxide is considered the most feasible advanced
26 oxidation process for TCE and PCE, and has been retained for further consideration.

27 **Advanced Oxidation (UV)** - Ultraviolet (UV) oxidation involves the passage of contaminated
28 groundwater through a reactor where it is irradiated by UV radiation for predetermined time period. The
29 retention time is determined by the type and concentration of organics in the groundwater, and the
30 strength of the UV source lamp. The absorption of ultraviolet light by the contaminants results in the
31 organic molecules being oxidized to carbon dioxide and water if sufficient dissolved oxygen is present.
32 The treated water can then be discharged for further treatment, or to its end use.

33 The process is most effective for oxidizing higher molecular weight organic compounds that already
34 incorporate oxygen in their respective chemical structures. The UV absorption process is relatively new
35 and so there is no large body of data available regarding its performance at the present time. Also, the
36 energy for the UV radiation that is supplied by electricity to the lamps is a significant power requirement.

1 Initial Screening - Advanced oxidation using UV is considered potentially feasible because it is a recently
2 demonstrated destructive technology for TCE and PCE, and has been retained for further consideration.

3 **10.7.4 Reverse Osmosis**

4 Reverse osmosis is primarily used for the removal of inorganic constituents from water, but may have
5 some application for removal of organic compounds. Reverse osmosis involves pressurizing the water
6 to cause it to selectively flow through a fine pore, semipermeable membrane, which acts to block the
7 passage of the ionic constituents and the larger organic molecules. Groundwater pre-treatment and post-
8 treatment is required.

9 Initial Screening - This technology is undemonstrated for chlorinated organic compounds and has not been
10 retained for further evaluation.

11 **10.7.5 Ion Exchange**

12 Ion exchange is primarily used for the removal of inorganic constituents from contaminated water
13 (demineralization). It has some application for removal of certain organic constituents in a manner
14 similar to ion exchange demineralization. Ion exchange involves the replacement of ions from an organic
15 resin with other ions from water. These ionic resins may also have the ability to either undergo ion
16 exchange phenomena with organic functional groups, or else physically adsorb the VOC constituents from
17 the contaminated groundwater.

18 Initial Screening - This technology is undemonstrated for chlorinated organic compounds and has not been
19 retained for further evaluation.

20 **10.7.6 Precipitation**

21 Precipitation separates the contaminants out of solution by altering the chemical equilibria to reduce the
22 contaminants' solubility. This allows the contaminants to settle out of the groundwater in the solid phase.
23 This technology is primarily used to precipitate metals from groundwater.

24 Initial Screening - This technology is undemonstrated for chlorinated organic compounds and has not been
25 retained for further evaluation.

26 **10.7.7 Air Sparging**

27 In this process, air is injected into the saturated matrix thereby creating an underground stripper that
28 removes contaminants through volatilization. This process is designed to operate at high air flow rates
29 in order to affect volatilization (as opposed to the lower air flow rates used to increase groundwater
30 oxygen concentrations to simulate biodegradation). Air sparging must operate in tandem with soil vapor
31 extraction (SVE) systems that capture VOCs stripped from the saturated zone. Depth of contaminants
32 and specific site geology are some factors that limit the applicability of the process.

33 Initial Screening - Only limited information is available on air sparging. Also, because of the large plume
34 area, this process has not been retained for further evaluation.

10.7.8 Vacuum Vapor Extraction

Air is injected into a well, lifting contaminated groundwater in the well and allowing additional groundwater flow into the well. Once inside the well, some of the VOCs in the contaminated groundwater are transferred from the water to air bubbles which rise and are collected at the top of the well by vapor extraction. The partially treated groundwater is never brought to the surface; it is forced into the unsaturated zone, and the process is repeated. As groundwater circulates through the treatment system in-situ, contamination concentrations are gradually reduced. This process is still in pilot-scale status, and factors such as depth of saturated and unsaturated zones and soil permeability may affect the applicability.

Initial Screening - This process is a pilot-scale process. Hence, it has not been retained for further evaluation.

10.7.9 Hot Water or Steam Flushing/Stripping

Steam is forced into an aquifer through injection wells to vaporize VOCs and semi VOCs. Vaporized components rise to unsaturated zone where they are removed by vacuum extraction and treated. Soil type may significantly impact the process effectiveness. This process has only been demonstrated on pilot-scale projects.

Initial Screening - Since this process has not been demonstrated at full scale. Hence, it has not been retained for further evaluation.

10.8 OFF-SITE TREATMENT

This technology requires that contaminated groundwater be transported off-site for treatment. Process options for this technology include POTW, and RCRA facilities licensed to treat contaminated wastes.

10.8.1 Publicly Owned Treatment Works

A local POTW is used to treat the extracted groundwater. Groundwater quality and flow rates must be determined to ensure that the POTW can effectively treat the additional loading without violating its discharge permit. Pre-treatment to reduce TCE and PCE concentrations may be required before treatment by the POTW.

Initial Screening - Using a POTW for treatment is considered potentially feasible because the POTW treatment system has the ability to treat TCE and PCE, and has been retained for further evaluation.

10.8.2 Resource Conservation and Recovery Act Facility

Extracted groundwater is transferred to a RCRA facility, usually by truck, for treatment. Although the groundwater is not considered a RCRA hazardous waste, the water would be treated by a RCRA-permitted facility. This process option is limited to small volumes of contaminated waste that can be easily transported in drums for treatment.

1 Initial Screening - This technology is not feasible for large volumes of groundwater and has not been
2 retained for further evaluation.

3 **10.9 IN-SITU TREATMENT**

4 In-situ treatment technologies incorporate some of the same underlying biological or chemical or physical
5 processes discussed earlier but the reactions are applied to groundwater in the aquifer. The process
6 options are discussed separately and the initial screening summarizes all of them.

7 **10.9.1 Oxygen Enhancement with Hydrogen Peroxide**

8 In this in-situ biological process, a diluted solution of hydrogen peroxide is circulated throughout a
9 contaminated groundwater zone to increase the oxygen content of groundwater and enhance the rate of
10 aerobic degradation of organic contaminants by naturally occurring microbes. For best results, factors
11 that must be considered include redox conditions, saturation rates, presence of nutrient trace elements,
12 pH, temperature, and permeability of the subsurface material. This process is primarily designed to treat
13 non-halogenated VOCs and semi VOCs. Halogenated VOCs can be treated, but it may be less effective
14 and only applicable to some components within this group.

15 **10.9.2 Oxygen Enhancement with Air Sparging**

16 This is an in-situ biological process. Air is injected under pressure below the water table to increase
17 groundwater oxygen concentration and enhance the rate of biological degradation of organic contaminants
18 by naturally occurring microbes. Air sparging increases mixing in the saturated zone, which increases
19 the contact between groundwater and soil. Halogenated VOCs can be treated, but it may be less effective
20 and only applicable to some compounds within this group.

21 **10.9.3 Permeable Treatment Beds**

22 Downgradient trenches backfilled with GAC remove contaminants from groundwater as it passes through
23 the trench. This treatment is similar to GAC adsorption discussed in Subsection 10.7.1. Considering
24 constructibility, it is only practical for shallow contaminated zones.

25 **10.9.4 Chemical Oxidation**

26 An oxidizer is injected into the aquifer to degrade contaminants. Chemical oxidation is discussed in
27 Subsection 10.7.3.

28 Initial Screening - The in-situ treatment technology and its process options are not considered feasible due
29 to the large plume area and aquifer depth at Muscoy and have not been retained for further evaluation.

30 **10.9.5 Natural Attenuation with Monitoring**

31 Natural attenuation is the general term for subsurface processes which may act to reduce groundwater
32 contaminants to acceptable concentrations without active intervention. Such processes include dilution,
33 dispersion, biodegradation, adsorption, volatilization and chemical interactions with subsurface materials.

1 Consideration of this option requires evaluation of the specific contaminants, pertinent site conditions and
2 the particular process or processes which may be relevant. In addition, a thorough assessment and careful
3 monitoring must be conducted to confirm that the contaminant levels are being reduced at rates consistent
4 with the RA objectives. The monitoring should include tracking the direction and rate of movement of
5 the plume and evidence of the continued effectiveness of the process or processes. The remedy must also
6 include the responsibility for maintaining effective, reliable institutional controls to prevent inappropriate
7 use of the contaminated groundwater.

8 Natural attenuation is not the same as "no action" although it is often perceived as such. For natural
9 attenuation to be considered as a feasible remedial alternative, it must be demonstrated not only that a
10 particular process is likely to occur, but that the process is occurring and will continue to occur in a
11 manner that will provide a reliable remedy. An example of a potentially feasible natural attenuation
12 process would be the intrinsic biodegradation of a readily degraded contaminant (e.g., toluene and xylene)
13 by the native microbial community. Another example is the chemical reduction of hexavalent chromium
14 contamination to insoluble forms as the groundwater enters an anaerobic zone. Natural attenuation
15 processes are considered in the Superfund program on a case-by-case basis, and guidance on their
16 applicability is still evolving.

17 Initial Screening - Natural attenuation processes have not been demonstrated at the Newmark site, and
18 the site conditions and plume characteristics make it unlikely that natural attenuation processes are
19 occurring at rates effective in limiting the spread of contaminants at the site. Review of data from the
20 last 14 years (since the discovery of contamination in 1980) and estimates of the potential time that the
21 plume has migrated indicate that natural attenuation processes cannot be considered reliable for protection
22 of human health and the environment at this site. Therefore, natural attenuation has not been retained
23 for further evaluation.

24 **10.10 ON-SITE DISCHARGE OF TREATED WATER**

25 After a treatment option on the surface, the resulting water must be discharged. The following subsections
26 discuss options for on-site discharge of treated groundwater.

27 **10.10.1 Reinjection**

28 Treated groundwater is injected into the aquifer. This process can be used in conjunction with extraction
29 wells to accelerate or enhance capture of a contaminant plume. Injection wells are placed downgradient
30 of the plume. This creates a groundwater mound that can increase the groundwater gradient toward the
31 extraction wells. Pretreatment by pH adjustment and disinfection may be required to prevent the injection
32 wells from plugging due to chemical precipitation and biological growth.

33 Initial Screening - Using reinjection for discharge is considered potentially feasible because of the
34 suitability of the range of aquifer depths at Muscoy, and has been retained for further evaluation.

35 **10.10.2 Surface Drainage**

36 This process option discharges extracted and treated groundwater to the ground surface for percolation,
37 or into existing drainage systems. Discharge may occur either on site or off site depending on the

1 location of existing facilities. Treatment prior to discharge is normally required to meet discharge
2 standards of a NPDES permit.

3 Initial Screening - Surface drainage discharge is considered potentially feasible because of the availability
4 of surface drainage channels in the area, and has been retained for further evaluation.

5 **10.11 OFF-SITE DISCHARGE OF TREATED GROUNDWATER**

6 **10.11.1 POTW**

7 This process option disposes of the extracted groundwater into an existing municipal treatment facility.
8 Pretreatment may be required if the POTW can process the hydraulic loading but not the contaminant
9 loading, as discussed in Section 10.8. The local POTW's ability to process the additional hydraulic
10 loading must be determined to evaluate this option.

11 Initial Screening - Using a POTW for discharge is considered potentially feasible and has been retained
12 for further evaluation.

13 **10.11.2 Municipal Water Supply**

14 Extracted groundwater is treated and discharged directly into a municipal water supply system. An
15 evaluation is required to determine if the municipal water supply system can use the additional water.

16 Initial Screening - Using a municipal water supply for discharge is considered potentially feasible and has
17 been retained for further evaluation. This end use method is currently being employed in the Newmark
18 OU for the end use of treated groundwater.

11.0 EVALUATION OF TECHNOLOGIES AND PROCESS OPTIONS

After initial screening, the technologies and process options which remain were evaluated on the basis of effectiveness, implementability, and relative cost (EPA 1988a, 1988b). Evaluation at this stage emphasizes effectiveness; less effort is directed at implementability and cost evaluation. Hence, only "relative" costs are used for evaluation at this stage of screening. The evaluation criteria are further defined below.

Effectiveness - Each process option was compared to available process options within the same technology group. Each option was evaluated in terms of the potential effectiveness in meeting the remediation goals, the potential impacts to human health and the environment during the construction and implementation phase, and the reliability and the suitability of the process to remediate the site-specific contamination. This evaluation was qualitative, not quantitative, in nature and was based on engineering experience.

Implementability - Implementability measures the technical and administrative feasibility of the process option. Technical feasibility was used to eliminate the process options that were clearly ineffective or unsuitable for the site.

Administrative feasibility refers to the ability to obtain permits for off-site actions and the availability of treatment, storage and disposal services. The availability of necessary equipment and technical personnel is also included.

Relative Cost - Because only limited emphasis is placed on cost at this phase of the evaluation as per EPA guidance, relative capital and operation and maintenance (O&M) costs were used to compare technologies and process options. Estimated costs were based on engineering judgment, and they were classified relative to other process options in the same technology type as high, medium or low.

Only the most feasible process options are retained for subsequent development of alternatives. Where possible, one process option will be retained for each technology. If process options for one technology provide advantages under different conditions, separate alternatives will be developed using each process option.

Table 11-1 summarizes the results for technologies and process options evaluated in this section.

11.1 MONITORING

The monitoring technology does not have process options other than monitoring.

Effectiveness - Monitoring by itself does not protect human health or the environment. It does not reduce toxicity or the volume of contaminants in the aquifer. Monitoring is effective in that it is useful for maintaining a database of contaminant concentrations and movement through the different phases of a project.

Table 11-1

EVALUATION OF PROCESS OPTIONS FOR GROUNDWATER

General Response Action	Technology	Process Option	Effectiveness	Implementability	Cost *
No Action	Monitoring	Monitoring	Useful to maintain a database. Does not reduce risk.	Not acceptable as sole action	Low initial cost, low O&M.
Institutional Actions	Groundwater use restrictions	Alternate Water Supply	Good prevention of public health risk.	Relatively easy to obtain regulatory approval.	Potentially high initial cost, low O&M.
Collection/Treatment/End Use Collection	Extraction	Extraction Wells	Very good for extracting groundwater.	Relatively easy to obtain regulatory approval.	High initial cost, low O&M.
		Municipal Supply Wells	Good if wells are suitable.	Relatively easy to obtain regulatory approval.	High initial cost, low O&M.
Treatment	Physical/Chemical (On-Site)	Aqueous-Phase Granular Activated Carbon (GAC)	Effective VOC removal.	Relatively easy to obtain regulatory approval and to construct.	Medium initial cost, high O&M.
		Air Stripping with Vapor-Phase GAC Treatment of Off Gas	Effective VOC removal.	Relatively easy to obtain regulatory approval and to construct.	High initial cost, medium O&M.
		Air Stripping with Off Gas Treatment by Resin Based Adsorption (Padre System)	Effective VOC removal.	May be difficult to obtain regulatory approval and to construct.	High initial cost, medium O&M.
		Advanced Oxidation (Ozone)	Effective VOC removal.	Difficult to obtain regulatory approval.	High initial cost, high O&M.

Table 11-1 (Cont'd.)

EVALUATION OF PROCESS OPTIONS FOR GROUNDWATER

General Response Action	Technology	Process Option	Effectiveness	Implementability	Cost *
Treatment (Cont'd.) End Use	Physical/Chemical (On-Site) (Cont'd.)	Advanced Oxidation (Ozone/Peroxide)	Effective VOC removal	Difficult to obtain regulatory approval.	High initial cost, high O&M.
		Advanced Oxidation (UV)	Low for VOC removal when used by itself.	Difficult to obtain regulatory approval.	High initial cost, high O&M.
	Off-site	POTW	Good if capacity is available.	Regulatory approval depends on available capacity.	High initial cost, high O&M.
	On-site Discharge of Treated Water	Reinjection	Very good end use method.	Sometimes difficult to obtain regulatory approval.	High initial cost, low O&M.
		Surface Drainage	Good to very good	Sometimes difficult to obtain regulatory approval.	Low initial cost, very low O&M.
	Off-site Discharge of Treated Water	POTW	Good if capacity is available.	Regulatory approval depends on available capacity.	High initial cost, high O&M.
		Municipal Water Supply	Good if capacity is available.	Relatively easy to obtain regulatory approval.	Low initial cost, high O&M.

Process option that is screened out.

* Relative cost is used for comparison.

1 **Implementability** - It is typically not implementable on its own due to public and government regulations
2 and is usually implemented as a component of an alternative.

3 **Relative Cost** - Monitoring has a comparatively low initial cost and low O&M costs.

4 **Evaluation** - The groundwater monitoring technology has been retained for development of alternatives
5 as required by the NCP.

6 **11.2 GROUNDWATER USE RESTRICTIONS**

7 Only one process option, alternate water supply, is associated with the groundwater use restriction
8 technology.

9 **Effectiveness** - An alternate water supply designation is effective in preventing public ingestion of
10 contaminated water; however, this technology does not reduce toxicity, mobility or volume of
11 groundwater contamination.

12 **Implementability** - Groundwater use restrictions can only be implemented if there is an adequate alternate
13 water supply available or that can be made available. Installation of additional municipal supply wells
14 in uncontaminated areas may be required. The technology and equipment needed for well installation
15 is readily available. Regulatory approval is relatively easy to obtain.

16 **Relative Cost** - There is no cost associated with restricting groundwater use, unless the restriction
17 requires installation of new municipal water production wells. In that case, there would be a high initial
18 cost and low O&M costs.

19 **Evaluation** - Groundwater use restrictions have not been retained for development of alternatives because
20 many production wells have already been contaminated. Replacement of these wells in uncontaminated
21 areas would require a significant amount of piping to reach the treatment systems, which is not feasible.

22 **11.3 EXTRACTION**

23 The extraction technology is the first component in the collection/treatment/end use general response
24 action. Two process options, extraction wells and municipal supply wells, are available within this
25 technology. To be effective, extraction depends on a number of factors, such as proper site location,
26 screen depths, and possible pumping rates. To accomplish determining the various quantities, site
27 groundwater modeling is typically undertaken.

28 **11.3.1 Extraction Wells**

29 **Effectiveness** - Extraction wells are effective in extracting contaminated groundwater over the plume area
30 at the required depth. Extraction of contaminated groundwater is very effective in reducing further
31 migration (and ultimately reducing the extent) and the volume of contaminated groundwater. This meets

the interim RA objectives to inhibit further migration of the plume. Wells are also effective in the short-term because workers and the public are not exposed to contaminated groundwater during construction.

Implementability - Because of their common use, implementation of the extraction well process option is relatively easy. Extraction well technology and equipment are available for virtually any aquifer condition. Regulatory approval is generally easy to obtain.

Relative Cost - Extraction wells have a relatively high capital cost, but a low O&M cost.

Evaluation - Extraction wells have been retained for development of alternatives because they are effective in meeting the interim RA objective to inhibit further migration of the plume.

11.3.2 Municipal Supply Wells

Effectiveness - Municipal supply wells are effective in meeting the RA objective of preventing ingestion of contaminated groundwater. However, municipal supply wells may not be as effective as extraction wells in inhibiting plume migration because existing wells are not designed (in location, screen depth, and operation) to optimally contain contamination. If new supply wells are installed in conjunction with a treatment system, it would be advantageous to design these wells with the characteristics of an extraction well to maximize the inhibition of further plume migration.

Implementability - Implementation of existing supply wells is easy. A treatment process will be required to meet drinking water standards. Municipal supply wells have the same implementability characteristics as extraction wells.

Relative Cost - If existing wells are used, the initial capital cost is very low. Installing new production wells has a relatively high capital cost, but a low O&M cost.

Evaluation - Municipal supply wells have been retained for development of alternatives, and are discussed further in Section 13.0.

11.4 PHYSICAL/CHEMICAL TREATMENT (ON-SITE)

Several process options are evaluated for the physical/chemical technology to meet the treatment general response action. The number of treatment options will be reduced to retain the most feasible processes for development of alternatives. As alternatives are developed through the FS process, treatment technologies screened out may need to be revisited as more information is obtained.

11.4.1 Aqueous-Phase GAC

Effectiveness - Aqueous-phase GAC is very effective in removing VOCs because it is able to obtain higher removal efficiencies than air stripping for the higher molecular weight constituents. It does not result in the generation of a liquid- or gaseous-phase effluent stream that requires further treatment before final discharge, and requires no additional fans or pumps for operation. The GAC process has the disadvantage of generating spent carbon contaminated with the collected VOCs. These materials require disposal by landfilling or incineration, and may be classified as hazardous waste. If the carbon is

1 regenerated to facilitate reuse, this regeneration step must be carried out by a relatively complex process
2 at an on- or off-site location.

3 **Implementability** - Aqueous-phase GAC is a commercially proven technology for VOC removal from
4 contaminated groundwater with a number of successful installations already in place. Because it is a
5 familiar technology, GAC systems are relatively easy to implement with respect to regulatory approval
6 and construction. The GAC system is more complex in its operation than a similar air stripping system
7 because of the periodic need for bed backwashing and carbon regeneration replacement.

8 **Relative Cost** - Aqueous-phase GAC system may have a higher initial cost than an air stripping unit of
9 comparable treatment capacity if air stripper off-gas treatment is not required. Carbon must be
10 periodically replaced, using either new or regenerated carbon. The GAC system has a higher O&M cost
11 than air stripping.

12 **Evaluation** - Aqueous-phase GAC has been retained for development of alternatives.

13 **11.4.2 Air Stripping with Vapor-Phase GAC Treatment of Off Gas**

14 **Effectiveness** - Air stripping with vapor-phase GAC treatment of off gas is very effective in that it is able
15 to achieve a very high removal efficiency for lighter, more volatile constituents. Air stripping provides
16 predictable performance for removal of VOCs at both high and low concentrations. Air stripping has the
17 disadvantage of requiring electrical energy for the movement of both the air and water streams through
18 the stripping tower. Periodic cleaning with sodium hypochlorite or an acid solution may be required to
19 control scale formation and biological growth on the packing material surfaces when mineral-laden waters
20 are being treated. Air stripping with vapor-phase GAC treatment of off gas meets the RA objectives for
21 both protection of human health and the environment in that it reduces the volume of contaminants in the
22 groundwater.

23 **Implementability** - Air stripping with vapor-phase GAC treatment of off gas is a proven technology with
24 a number of successful installations already in place. This system is easily implemented with respect to
25 permitting and construction, and provides simple, reliable operation over extended periods of time.

26 **Relative Cost** - Overall, air stripping with vapor-phase GAC treatment of off gas has a relatively high
27 capital cost and medium O&M costs.

28 **Evaluation** - Air stripping with GAC treatment of off-gas will be retained for development of alternatives
29 due to its established effectiveness for large volumes of groundwater.

30 **11.4.3 Air Stripping with Off Gas Treatment by Resin Based Adsorption**

31 **Effectiveness** - As presented in Subsection 11.4.2, air stripping is very effective with very high removal
32 efficiency for lighter and VOCs such as TCE and PCE. Evaluation of off-gas treatment for the North
33 and South Treatment Plants at the Newmark OU (where groundwater contaminants are virtually identical
34 to the contaminants found at the Muscoy Plume OU) indicates that the resin based system can effectively
35 treat the off gas (URS June 1994).

1 **Implementability** - Although off-gas treatment by the resin based system is a new process, air stripping
2 is a proven process.

3 **Relative Cost** - This process has relatively high capital cost and medium O&M cost.

4 **Evaluation** - This process option has not been retained for development of alternatives because of
5 uncertainties about the effectiveness of the process under high flow, low concentration conditions expected
6 at the Muscoy Plume OU. The resin based system may be evaluated during the RD as an acceptable
7 BACT, but for estimation purposes, only vapor phase GAC will be evaluated for further development
8 of alternatives.

9 **11.4.4 Advanced Oxidation (Ozone)**

10 **Effectiveness** - The ozone oxidation process is effective, as it is able to achieve high degrees of VOC
11 destruction and is suitable for low inlet concentration streams. However, it is most often used to reduce
12 general organic contamination, and treatment of specific organic contaminants is only now being studied
13 extensively. A potential disadvantage is that toxic by-products may be formed that would require
14 additional removal equipment, increasing chemical oxidation process costs.

15 **Implementability** - Because it is a relatively simple process with relatively few pieces of equipment
16 required, it is easily implemented with respect to construction. Regulatory approval is difficult because
17 of the undemonstrated reliability as compared to conventional technologies.

18 **Relative Cost** - There are relatively high costs associated with the ozone oxidation process. The process
19 has a high energy requirement for ozone generation and a high ozone addition requirement, giving it a
20 high operating cost. The ozone can require a long contact time in order to carry the reactions through
21 to completion. This can result in a physically large process unit and an accompanying large capital cost.

22 **Evaluation** - The advanced oxidation process using ozone has not been retained for development of
23 alternatives because ozone alone is not able to completely oxidize TCE and PCE.

24 **11.4.5 Advanced Oxidation (Ozone/Peroxide)**

25 The criteria evaluation for this process is similar to that for the ozone oxidation process in the previous
26 evaluation, with the exception that ozone and hydrogen peroxide are used as oxidizing agents.

27 **Evaluation** - The advanced oxidation process using ozone and peroxide has been retained for
28 development of alternatives because this process is considered to be the most effective advanced oxidation
29 process for TCE and PCE.

30 **11.4.6 Advanced Oxidation (UV)**

31 **Effectiveness** - Ultraviolet photolysis is ineffective by itself to reduce VOC levels to the levels required
32 to meet ARARs for most contaminated groundwater conditions. The process is relatively simple, but may
33 require significant retention time by itself. It can also result in the generation of certain potentially
34 harmful intermediate by-products.

One method to increase effectiveness of VOC destruction by ultraviolet oxidation is to add an oxidizing agent. Ozone, hydrogen peroxide, or both chemicals are initially added to the contaminated groundwater to begin the process of oxidation. The oxidant-rich groundwater is then passed through the photolysis reactor where it is contacted with UV light, which provides the energy to substantially increase the otherwise relatively slow reaction rates.

Implementability - UV oxidation has the same implementability characteristics as ozone and ozone/peroxide destruction.

Relative Cost - The process has a relatively high initial cost and high O&M costs because of its associated electric power requirements.

Evaluation - The advanced oxidation process using UV has not been retained for development of alternatives because site information indicates that UV would not be required in the oxidation process with ozone and peroxide.

11.5 OFF-SITE TREATMENT

Off-site treatment can be accomplished by discharging extracted groundwater into the local sanitary sewer system for treatment at a POTW. The discharge to a RCRA facility as a process option was eliminated in the initial screening.

11.5.1 POTW

Effectiveness - This process is effective if the local sanitary sewer treatment facility can manage the additional volume of water and VOC loading. If capacity exists, this process option meets both RA objectives by reducing the volume of contaminants and prevents public ingestion of VOCs.

Implementability - Using a POTW for off-site treatment cannot be implemented because treatment capacity is unavailable. The expected load capacity from the Muscoy Plume OU treatment system would require an additional capacity of approximately 10 mgd, which is not possible to accommodate at this time.

Relative Cost - Using a POTW would have a relatively high initial cost of approximately \$4 to \$5 per gallon of wastewater capacity if the sewer and treatment systems require additional capacity. O&M costs are very high because of flow rate charges by the POTW.

Evaluation - The POTW treatment process option has not been retained for development of alternatives, because the necessary end use capacity is not available and the associated costs are high.

11.6 ON-SITE DISCHARGE OF TREATED GROUNDWATER

On-site discharge includes two process options, injection wells and surface drainage, as the possible end use component of the collection/treatment/end use general response action.

11.6.1 Reinjection

Effectiveness - Injection wells are effective because the locations and depths of reinjection can be selected to assist in management of the plume. Pretreatment may be required prior to injection to inhibit scaling and biological growth in the wells. The groundwater resource is also returned to the aquifer for future use. Injection wells are particularly feasible in highly permeable aquifers such as Muscoy, but they must be carefully designed and operated to ensure that they do not become plugged during operation.

Implementability - Discharge of treated groundwater into an aquifer may require substantial effort to obtain approval from appropriate agencies. The treatment must ensure that drinking water standards are met before injection. Injection wells have been demonstrated in many locations and equipment is available for construction. Existing models can be used to site and design the wells and their operation.

Relative Cost - The initial cost is relatively high compared to surface or municipal water supply discharge if these options are feasible. O&M costs are low if properly maintained. Given the ability to assist with management of the plume, benefits may accrue due to a shorter remedial duration.

Evaluation - Reinjection has been retained for development of alternatives.

11.6.2 Surface Drainage

Effectiveness - Surface drainage is a quick solution for discharge of treated groundwater if drainage facilities capable of accepting treated volumes of groundwater are available.

Implementability - Regulatory approval is sometimes difficult to obtain for surface drainage discharge. In addition, surface discharge of large volumes of treated water would likely not be considered a beneficial use of limited groundwater resources.

Relative Cost - Overall cost is relatively low if facilities are available. O&M costs associated with this end use process to maintain the drainage channel(s) are minor.

Evaluation - The surface drainage discharge option has not been retained for development of alternatives because this option would likely not constitute a beneficial use of the treated groundwater.

11.7 OFF-SITE DISCHARGE OF TREATED GROUNDWATER

11.7.1 POTW

The POTW end use option is similar to the POTW treatment option discussed in Subsection 11.5.1, except that the groundwater is treated prior to discharge to the POTW to reduce the contaminant loading.

Evaluation - The POTW end use process option has not been retained for development of alternatives because the necessary end use capacity is not available and the associated costs are high. In addition, POTW discharge would likely not be considered a beneficial use of limited groundwater resources.

1 **11.7.2 Municipal Water Supply**

2 This end use process option is used in conjunction with municipal supply wells or extraction wells with
3 treatment either at the wellhead or at an existing municipal treatment facility. Capacity must be available
4 in the potable water system or improvements must be made to implement this option. Refer to Section
5 11.3 for the evaluation of this process option with respect to off-site discharge.

6 **Evaluation** - The municipal water supply end use process option has been retained for development of
7 alternatives.